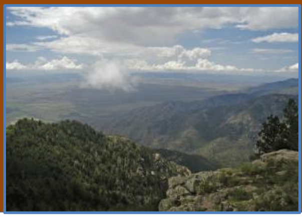
Madrean Archipelago Rapid Ecoregional Assessment



Issued November 2014

Together with partners, the Bureau of Land Management is conducting rapid ecoregional assessments covering much of the American West. These assessments look at large geographic regions and document key ecological resources, such as species and habitats, describe primary influences on these resources, characterize their status and trends, and provide tools and data to support future management and conservation decisions.

A key area of interest in the REAs is the assessment of climate change effects. Specifically, REAs use information from past observed climate and models of future climate to determine climate change trends and potential threats to conservation elements.

Climate Change Assessments

Three categories of assessments were conducted:

- Recent climate change trends assessment that compared historic and recent observations
- Recent climate change trend assessment that calculated statistically significant change within the last thirty years.
- Projected future climate change trends assessment that compared historic with modeled future climate
- Climate change risk assessment for conservation elements (CEs). This assessment overlaid all CEs on a climate change exposure index and modeled the future bioclimate envelopes of four ecosystem CEs.

Storm near Sonoita, AZ. Photo from capturemyarizona.com

Assessment Approach

The MAR REA climate trend assessment examined current trends and future projections in the magnitude, significance, and spatial and seasonal patterns of change in basic climate variables. Trend detection statistics were applied to highly vetted spatial climate data to quantify how much climate change has already occurred in recent decades, and to characterize future changes projected by various global climate models (GCMs) run under a moderately aggressive scenario of growth in future greenhouse gas emissions (the A2 scenario).

Climate Change Trend Metrics

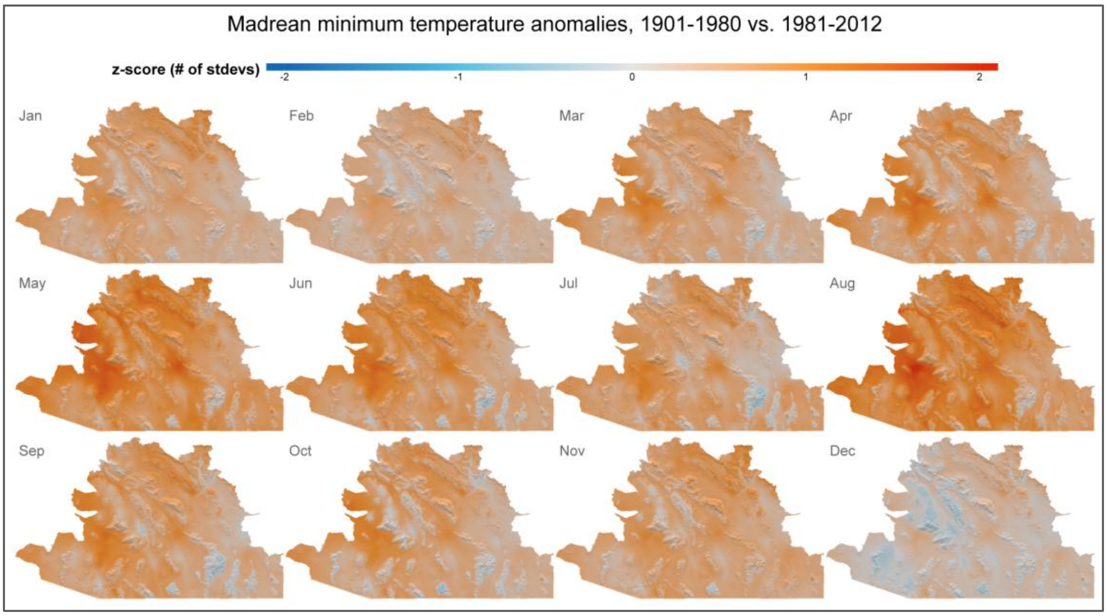
The climate change metrics used for assessment of both recent and future climate trends involve comparison between two time periods: a recent (1981-2012) and a future (2040-2069) time period compared to a 20th century baseline (1901-1980). These differences are expressed as "deltas" (amount of change) which show departure in actual units of climate (in degrees Celsius or mm of precipitation), and "anomalies" that show those deltas in relation to historical variability (in units of standard deviation from the baseline mean). Anomalies were then aggregated across the core climate variables (minimum temperature, maximum temperature, and precipitation) over all 12 months to derive a climate change exposure Index (CCEI).

Additional trend analysis calculates the magnitude and statistical significance of trends *within* the recent time period (as opposed to the above metrics that measure change compared to the 20th century baseline). This analysis quantifies the direction of climate change in recent decades, and whether there is a statistically significant trend in change (these results are discussed but not visualized in this brochure). A large number of data sets and analyses were generated for the MAR REA, only a small sample are presented in this brochure.

Products and Key Findings

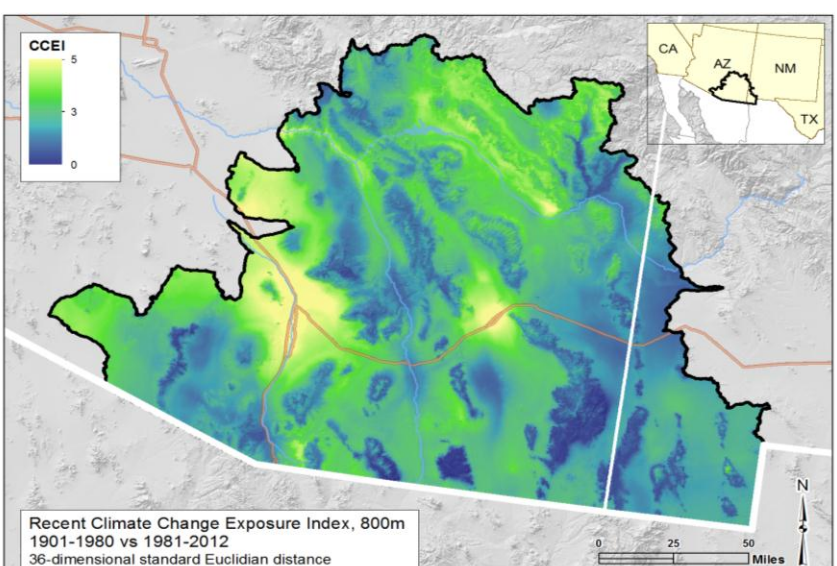
Recent Climate Trends

Statistically significant climate change is already occurring in the Madrean ecoregion, and these changes have a distinct spatial and temporal character. The increase in minimum monthly temperatures is the change that most frequently exceeds 20th century conditions across the largest area of the Madrean (figure below). Recent increases in monthly maximum temperatures are less dramatic, yet still statistically significant, principally in late spring and early summer, and primarily distributed in lower elevation areas. Precipitation has varied in the direction of change spatially and seasonally, although the magnitude of change remains well within the range of historical variability. Recent precipitation changes for most months exhibit drying trends (generally in northern and western portions of the MAR), and some regions of increasing precipitation (generally in eastern half of the MAR and at higher elevations).



Minimum temperature anomalies

Every month of the year exhibited minimum temperature increases across the majority of the ecoregion with notable departures from baseline variability (as much as +2 standard deviations). The greatest increases occurred during the spring months in low-lying western and northern parts of the MAR.

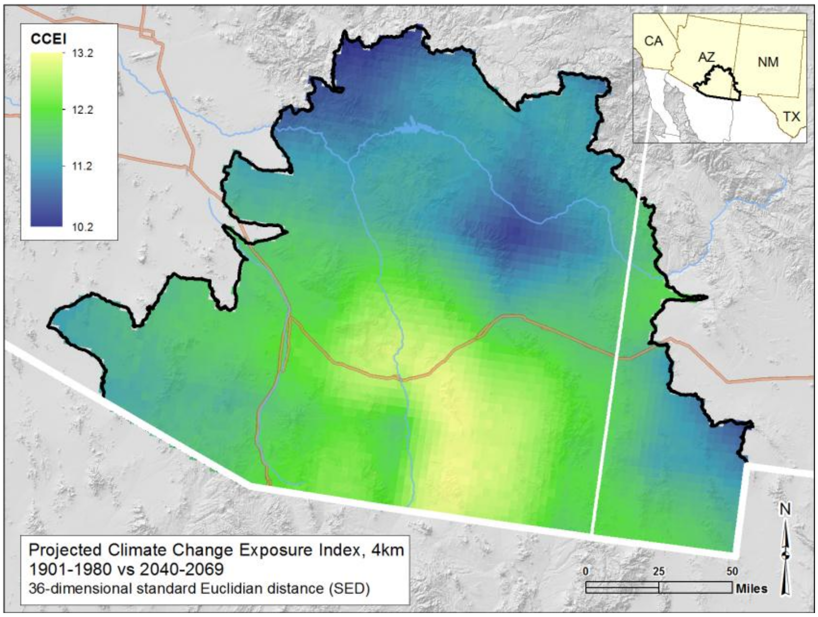


Climate change exposure index (CCEI), recent change

The CCEI is in units of standard deviation and ranges from 0-5. Blue colors represent less overall climate change exposure and yellow represents high exposure. These results suggest that lower elevation areas within the MAR experienced the most overall climate change between the baseline and the recent period, while mid- to high elevation climates remained relatively more stable. The highest overall change occurred in the area around Tuscon, AZ.

Future Climate Change

Based on the climate values projected by an average of GCMs, mid-century climate is projected to be well outside the range of 20th century climate across the entire MAR. Climate models project substantial increases in maximum and minimum temperatures by mid-century, with summer minimum temperature departures projected to be the most severe. Projections for moisture indices such as precipitation and climate moisture deficit (CMD) show a general drying trend during the months of April - August, with less change over the remaining months and slight precipitation increases for some fall and winter months.

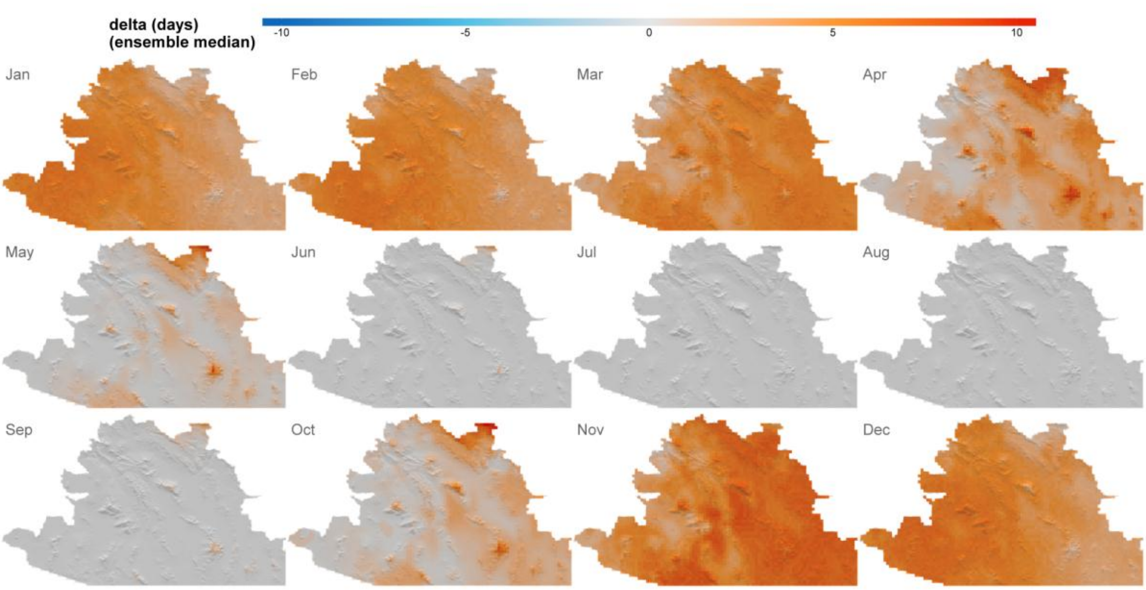


Projected Climate Change Exposure Index, 4km
1901-1980 vs 2040-2069
36-dimensional standard Euclidian distance (SED)

Climate Change Exposure Index (CCEI), future change

Relatively speaking, the northern MAR is projected to experience less overall climate change than the central and southern regions. The future CCEI summarizes departure for monthly climate variables in units of standard deviation from the baseline mean. While possible values range from 0-13.2, all values in the MAR are significant with a range of 10.2-13.2. This map is scaled to reveal patterns but all areas are expected to experience significant change.

Madrean projected number of frost-free days deltas, 1901-1980 vs. 2040-2069



Projected Future departures in Number of Frost-Free days (NFFD)

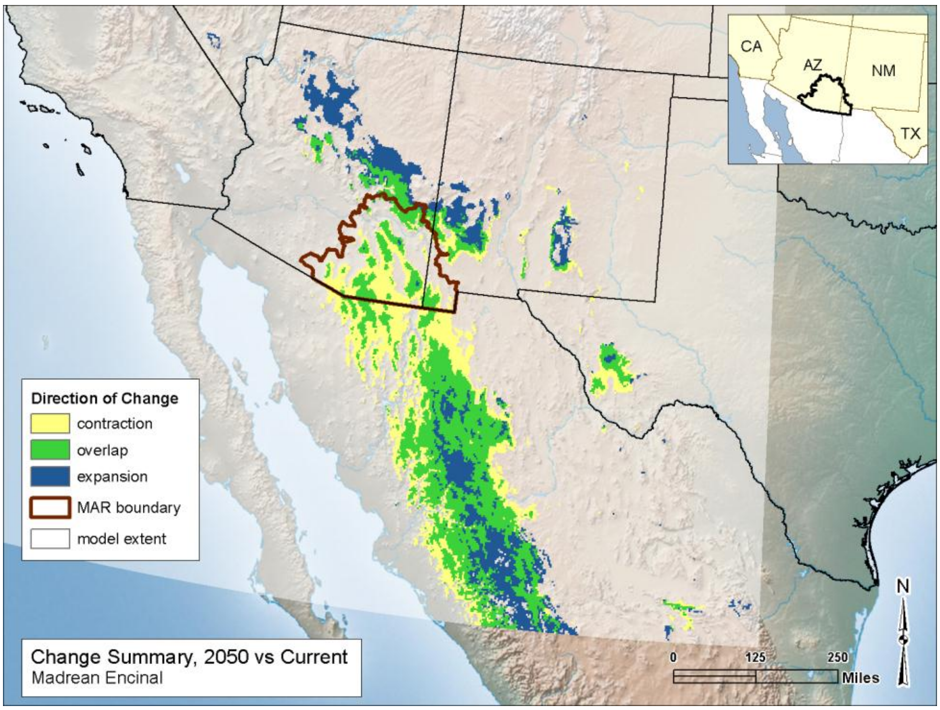
All months, other than summer months where there is historically little to no frost, are projected to see increases in NFFD. The average length of the growing season (frost-free period) is projected to increase dramatically, with the frost-free period increasing by anywhere between 25 days (in the eastern MAR) and 55 days (in the west).

The greatest changes occur in the shoulder season months of April and November, where high elevations are projected to see up to 10 fewer nights of temperatures falling below 0 degrees C.

Key Findings and Limitations

CE Risk Assessments

Two methods were used to assess how conservation elements (CEs) may be exposed to climate change in the future: 1) simple graphic overlays of the CE distribution maps with the future climate change exposure index (maps not shown) , and 2) Bioclimatic envelope models that project the distribution of future suitable climatic conditions for a given CE. A bioclimatic envelope is the combination of climatic conditions which is described by a species' known distribution. The model estimates a CE's suitable bioclimate by relating known current CE localities to current climate variables, and projects where in geographic space similar climate conditions occur in the present and under future scenarios. These results suggest which portions of the current CE range may experience the greatest and least climate stress in future decades by showing projected expansion, contraction, and stability of suitable bioclimate (see below).



Change Summary, 2050 vs Current
Madrean Encinal

Summary of modeled expansion, contraction, and stability

Contraction areas are where suitable climate for the conservation element currently exists but may not in the future; overlap is where both current and future climate are suitable (these may be areas of stability); and expansion is where current climate is not suitable but is projected to be in the future. Suitable bioclimate for the Madrean Encinal is projected to contract at lower elevations and move upslope, while mid-elevations are projected to remain stable.

Limitations

Any effort to understand the impacts of future climate change on biodiversity requires outputs from global circulation models (GCMs), which have to be downscaled to an interpolated climate surface of recent climate observations. All of these factors (interpolation, downscaling, and GCMs) have inherent uncertainties. Interpolation (the estimation of unknown values based on surrounding data points) is restricted to scattered weather stations, whose density patterns generally reflect patterns of human settlement and are inherently biased towards easily accessible, low elevation sites. Thus remote areas and regions of high topographic complexity have greater uncertainty in gridded climate data used for trend detection and downscaling. The process of downscaling has its own limitations: it assumes the relationship between macro and microclimates remains constant over time. GCMs often differ in magnitude and direction of change in future climate, and effects like regional or local interactions between land-surfaces and climate are not usually captured. One way of addressing uncertainty is to analyze multiple climate model outputs. For all climate change analyses in the MAR, an ensemble of multiple GCMs was used (for example, analyzing the degree of model agreement for a bioclimatic envelope model).

In addition to limitations in the climate data, bioclimatic envelope models make several simplifying assumptions: they do not account for the varying dispersal ability of different taxa, they do not consider genetic or evolutionary adaptive potential across individuals or populations, and they do not account for the influence of biotic interactions. This is why results of bioclimatic envelope modeling should not be interpreted as shifts in CE distributions, but rather potential shifts in estimated suitable climate conditions defined by the CEs' locality data.